Vibracoring on the New Jersey Shelf: Investigating the Stratigraphic Response to ~50,000 Years of Eustasy

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LONG-TERM GOALS

(1) Establish the geologic history of sedimentary processes on the New Jersey shelf (Fig. 1) over the last ~50,000 years, particularly focusing on the nature of shelf-edge sedimentary wedges, including the formation and preservation of sand bodies (Gulick et al., 2005), the paleoclimate associated with outer-shelf channel formation and subsequent infilling (Nordfjord et al., 2005), cross-shelf transport of sediments at or near lowstand (Goff et al., 2005), and the influence on the preserved stratigraphy of large sediment outflows associated with postulated glacial lake collapses during the last deglaciation (Fulthorpe and Austin, 2004).

(2) Interact with ONR-funded acoustic programs on the New Jersey shelf to provide the capability for modeling geoacoustic properties of the shallow seabed in three dimensions

OBJECTIVES

Our primary objective was to sample shallow stratigraphic targets on the New Jersey middle and outer continental shelf (Fig. 1). This part of the east coast margin has been the focus of a number of high-resolution geophysical surveys and sampling efforts over the past two decades, funded principally by the Office of Naval Research (ONR). These data combine to form a detailed picture of the shallow stratigraphy related to the last ~50,000 years of eustacy on this shelf. Samples collected during KN190 and subsequent analyses will provide additional geologic ground truth as to the timing, depositional environments, and physical properties of the imaged strata. The principal stratigraphic targets are illustrated on one of the central dip lines through the survey area (Fig. 2). These include: (1) a regional reflector, “R”, formed about 40,000 years ago; (2) two sequences of sediment wedges on the outer shelf, identified as the “outer shelf wedge” and “shelf edge wedge” (separated by the prominent reflector “W”, see Fig. 2), which were likely deposited during sea level fall prior to the Last Glacial Maximum (LGM); (3) channels formed by fluvial downcutting during the LGM, and later filled with an estuarine sequence during Holocene sea level rise; (4) a ravinement surface, ”T”, created by shoreface erosion during transgression, which is associated with a lag deposit of coarse-grained

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sediment; and (5) the surficial sand sheet veneering the seafloor, formed during the Holocene into sand ridges up to 10 m thick. Key references supporting this work include: Duncan (2001), Duncan et al. (2000), Goff et al., (1999; 2004; 2005), Gulick et al. (2005), Nordfjord (2005), Nordfjord et al. (2005; 2006).

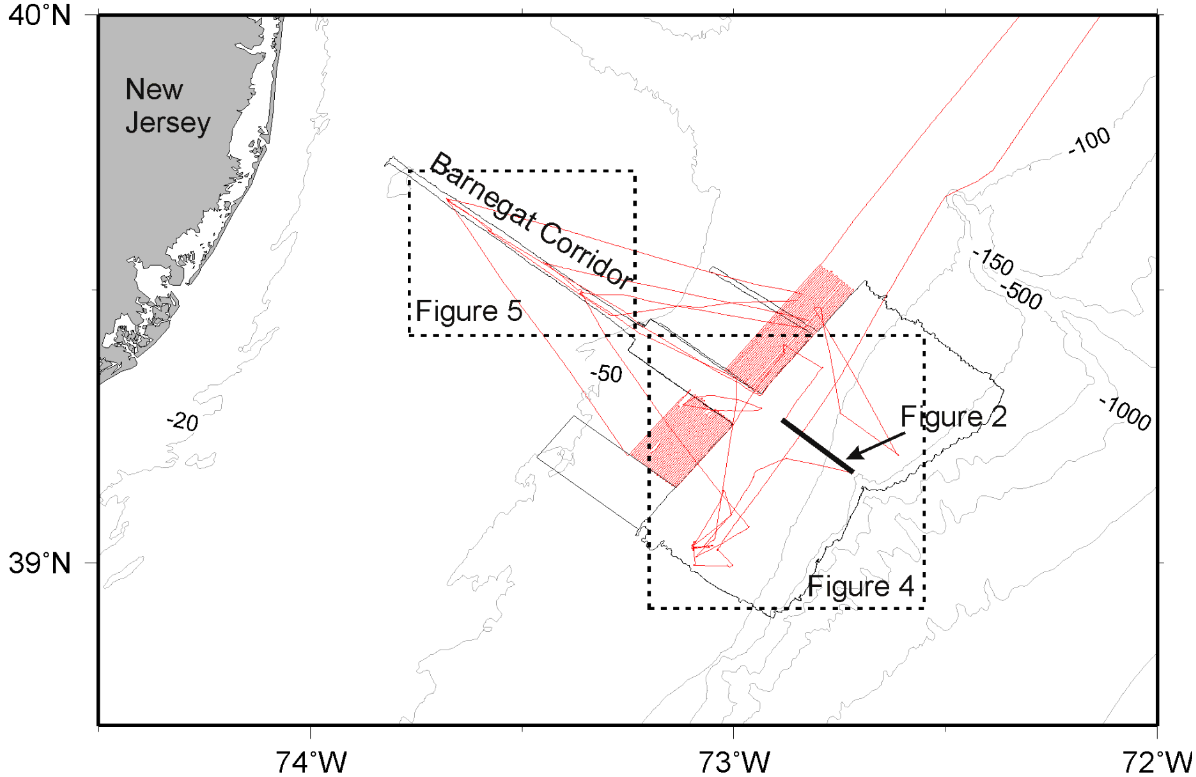

Figure 1. Location map of survey area on the New Jersey shelf. Bathymetric contours in meters. Black outline indicates prior multibeam bathymetric coverage. Red lines indicate KN190 cruise tracks.

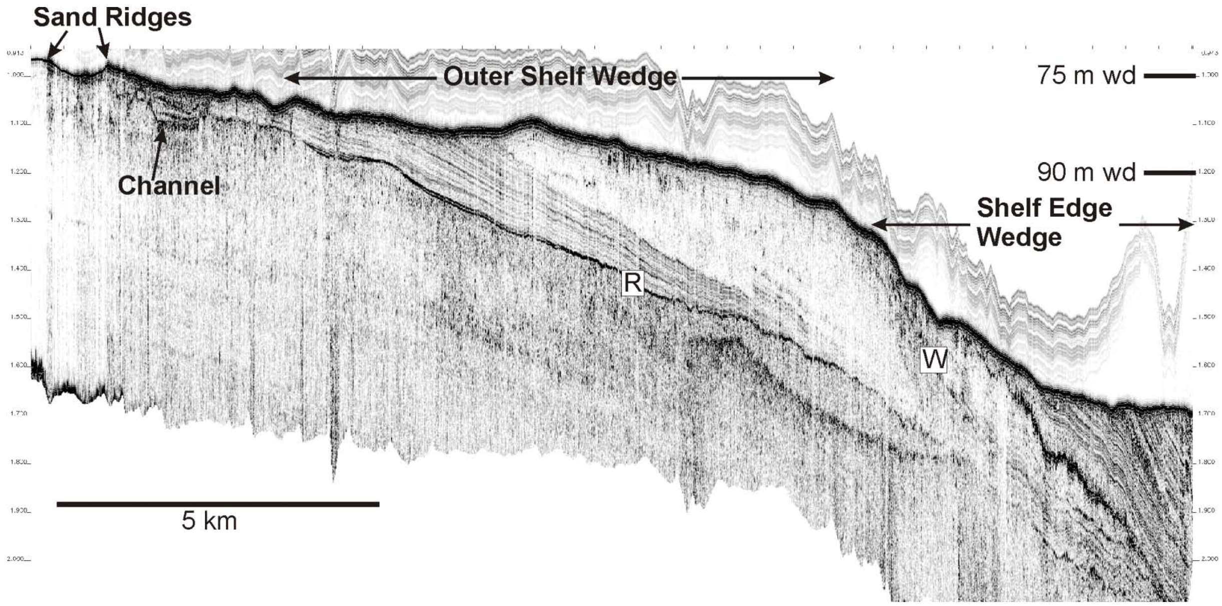

Figure 2. CHIRP seismic dip line on New Jersey outer shelf, illustrating primary stratigraphic components that were targets of sampling on the KN190 cruise. Location shown in Figure 1.

APPROACH

Our original plan called for collecting cores using the AHC-800 (Active Heave Compensation to 800 m) drilling system, which was developed and is operated by the DOSECC (Drilling, Observation and Sampling of the Earths Continental Crust) consortium. The AHC-800 is a modified version of DOSECC's lake-drilling system, which generally operates off moored barges. The AHC-800 system was developed with ONR funds, and for its first deployment was used for the ONR-sponsored Geoclutter project on the New Jersey shelf in October 2001. Austin was the PI for that cruise, and John Goff was a participant. Because the AHC-800 was still in development at that time, a large part of the 2001 cruise was spent overcoming technical issues, including working with a temperamental dynamic positioning system aboard *Knorr* and fine-tuning the complex heave compensation software driving the drilling platform. We were also beset by severe weather conditions owing to the lateness of the season. Nevertheless, we had success coring to ~13 m depth below the seafloor at one site, and our anticipation was that a follow-up cruise with the AHC-800 would yield excellent results. That cruise was finally to become a reality on KN190, after funds were raised from several sources, including ONR (who provided the ship time), industry (Norsk-Hydro and ExxonMobil), and with Jackson School of Geosciences matching support. Unfortunately, DOSECC pulled out of the contract just a few months prior to the cruise. (Their reason was that the person who developed the system, and who is the only one who can run it effectively, decided that he was overcommitted and could not give the AHC-800 the pre-cruise preparation that it required.)

After consulting with our sponsors and collaborators, we decided to press on with the cruise using a commercial vibracoring system. This option was attractive for two reasons: (1) we would be able to attempt to core in many more locations (perhaps 10 times as many) than would have been possible with the AHC-800, and (2) with our vast collection of chirp seismic data, we could pinpoint erosional windows that that would allow us to sample most of our target strata with shorter cores, avoiding in most locations the difficult-to-recover Holocene sand layer. We did not feel that waiting another year was a viable option, given both personnel commitments and difficulties in scheduling the *Knorr* (which is the only UNOLS vessel from which the AHC-800 could operate; an improved DP system had been installed following the 2001 AHC-800 cruise) for an optimal weather window. To try to maximize our recovery, we decided to operate with the most powerful vibracore available: an Alpine pneumatic system supplied by Sea Surveyor, Inc. (SSI) (Figure 3a). We selected SSI following a competitive bid process. Using such a system was in itself a significant challenge, because they are typically operated only in shallower water. However, along with the SSI contractors, we felt that the water pressure issues could be overcome by operating with a larger air compressor and stronger hoses.

WORK COMPLETED

Operation of the vibracorer did not, unfortunately, go as expected. We encountered two obstacles that made it largely impossible to carry out our planned scientific mission: (1) recovering the vibracorer air hoses (armored to withstand hydrostatic pressures to be expected at water depths of >100 m) was a far more taxing manpower task than originally anticipated, preventing us from operating in water depths more than ~80 m and on a 24-hr a day schedule, and (2) despite getting what appeared to be sufficient air pressure to the seafloor, the vibrating mechanism failed to operate effectively in water depths more than ~50 m.

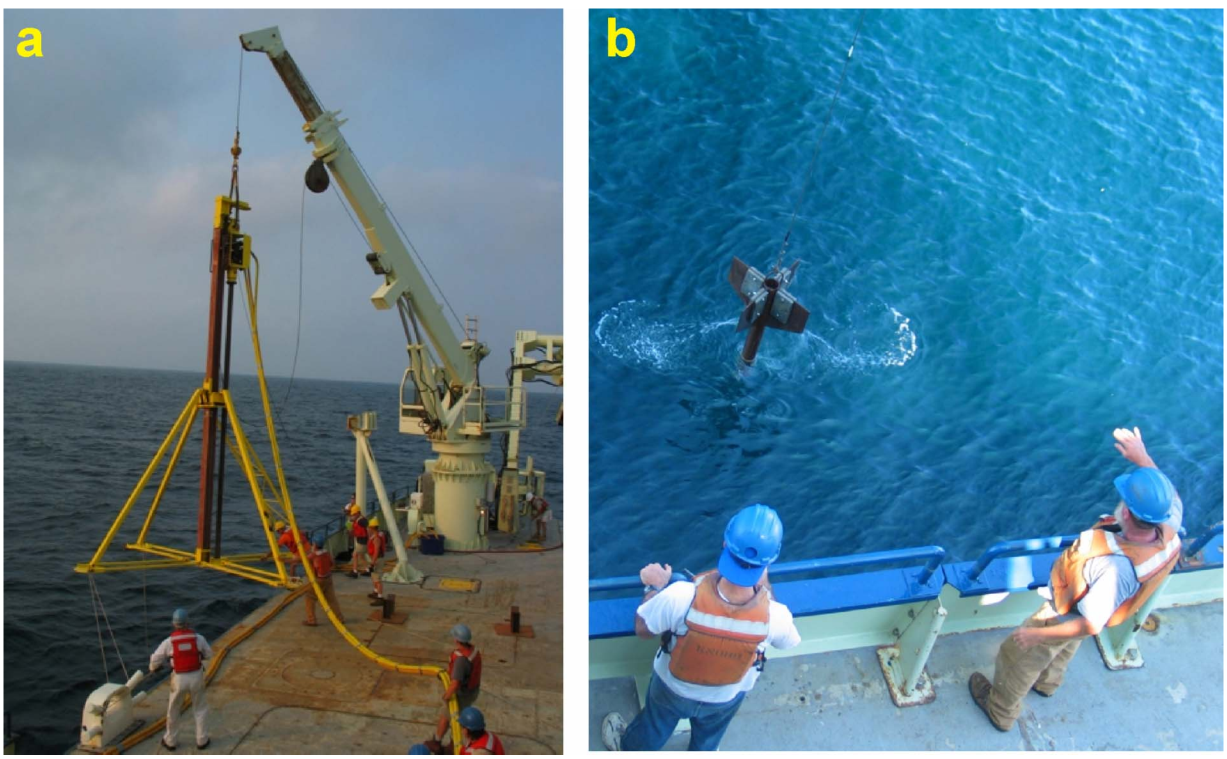

Figure 3. Instrument deployment: (a) vibracorer and (b) gravity corer.

In SSI's previous vibracoring experience, air hoses could readily be deployed and brought back on board with a few crew, particularly since, being filled with air, they tended to float to the surface as the vibracorer was hauled back to the ship. However, with the reinforced air hoses purchased for this job, they were considerably heavier and did not readily float to the surface. In addition, after a few deployments, the air hoses became heavier still as water infiltrated between inner and outer liners, outside the metal armoring. Hauling in the air hoses required more personnel than we had budgeted for a single 12-hour shift, and eventually became too arduous for the outer continental shelf water depths that we envisioned. To deal with the manpower issue, after 6 days of operation we went to a single 12-hour shift for coring operations. This worked well, as we were able to be very efficient and productive during that time. On average, an entire vibracoring operation took ~1.5 hr.

The most serious issue was the generally poor performance of the vibracorer in water depths >50 m; the reason is still a mystery to us. As evidenced by the air coming out of the return air hoses at these depths, we appeared to be getting sufficient air through the vibracoring mechanism. Nonetheless, the head simply wasn't vibrating with sufficient energy for significant penetration. This was most in evidence to those handling the air hoses. As the vibracorer was lowered to the seafloor, it would always be vibrating during the descent, and the vibration could at first be felt through the hoses on deck. However, below ~50 m water depth, such hose vibration became much more attenuated, to the point where it could not be felt by handlers. That the vibracore was indeed vibrating to some degree while on the seafloor at these depths was evident by the fact that the nose cone became highly polished (at least when deployed at sandier sites), but negligible penetration of the core barrel was usually achieved. Occasionally, we did obtain vibracores up to ~2 m long in softer sediments. Sample locations in deeper water are shown in Figure 4.

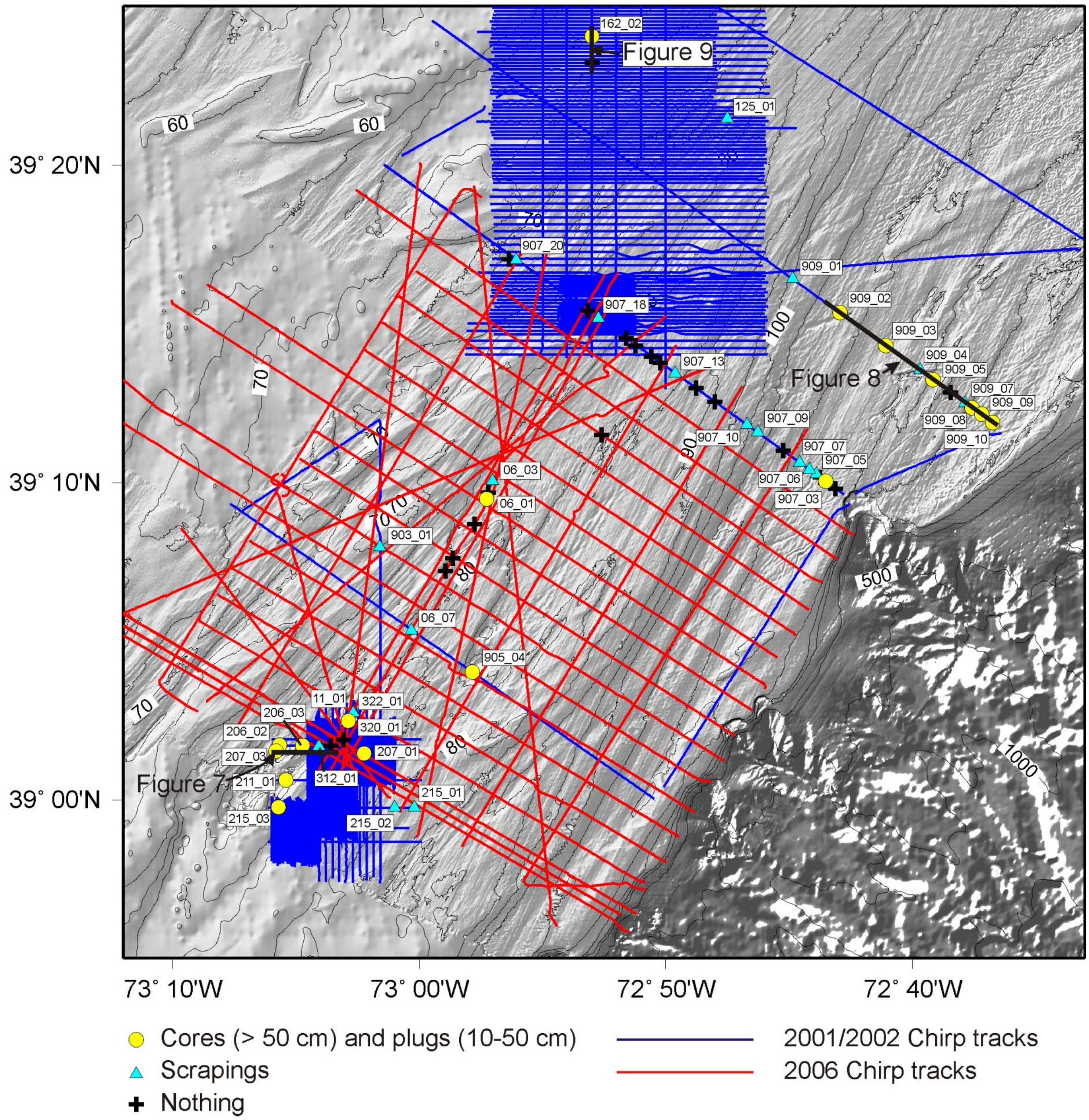

Figure 4. Location map for all cores collected and attempted on the outer New Jersey shelf. Bathymetric map (contours in meters; artificial illumination from the North) is a combination of available multibeam and archival data. CHIRP seismic reflection track lines from ONR-funded work (2001-02; 2006) are shown.

To see if vibracorer performance improved in shallower depths, we selected a number of coring sites within the Barnegat Corridor (Fig. 1), in ~25-35 m of water, where we also had substantial bathymetric, CHIRP seismic and grab sample data (funded by Joint Oceanographic Institutions, Inc.). However, not having anticipated coring in this region, we only had illustrations of seismic profiles with us, rather than the digital CHIRP seismic data for that area, so navigation was not as precise as would normally have been the case. These data were first published in Duncan's (2001) thesis, and are now the topic of a paper by Goff and Duncan on sand ridges recently submitted to Sedimentology.

Our first Barnegat Corridor core, through a sand ridge, was > 4.5 m long; subsequent coring in this area proved that the vibracorer was more successful in the shallower water depths. We ultimately spent two full 12-hour shifts coring in the Barnegat Corridor, targeting a second sand ridge, two channels and the mid-shelf sediment wedge. One core through a channel fill included a core nearly 6-m long, our best recovery of the cruise.

Gravity Coring

Our difficulties with operating the vibracorer on the outer shelf prompted us to try utilizing a gravity corer provided by SSI as a contingency tool to obtain more samples in our primary middle-outer continental shelf working area (Fig. 1). The gravity corer (Fig. 3b) was 1 m long and weighted on its fins with 200 lb of lead. Deployment was very simple and quick, and could be accomplished during weather conditions that otherwise precluded operating the vibracorer. More than 100 gravity core casts were conducted. When successful, the gravity corer penetrated the surface mixed layer to obtain a plug of stiff clay in the nose cone, which can be assumed to represent undisturbed, in situ sediment samples of the tops of the outer shelf and shelf edge wedges. In general, we tried to make three attempts at sampling each site chosen, unless it was clear that the seafloor was sandy and unreceptive to the gravity core. Additional sites were chosen to try to maximize sampling of the wedges within erosional windows. Where cores were unsuccessful, we were often able to obtain either a scraping of clay/mud from the outer barrel, or shelly/sandy material caught in the core catcher. We bagged all samples we deemed significant enough to keep. All gravity core locations are shown in Figure 4.

Core Processing and Logging

Cores from successful vibracorer attempts were cut, where appropriate, into 1.5 m-long sections. Each section was logged in the Multi-Sensor Core Logger (MSCL) (Fig. 5a) for acoustic velocity (230 kHz), gamma-ray density, and magnetic susceptibility. Cores were then stored in a refrigerated van for post-cruise transport to the Core Repository at the Lamont-Doherty Earth Observatory for preliminary processing (expected in September 2007). This will include splitting, digital photography, and visual geologic description. Several core sections were split onboard for preliminary examination and for educational purposes (Fig. 5b). These cores were photographed and graphically described, and later stored in D-tubes in the refrigerated van and transported with the unsplit cores to Lamont.

Short gravity cores were extracted to preserve as much stratigraphic context as possible. Often the available core consisted only of a ~10-15 cm plug in the nose cone/core catcher, with a roughly equal amount of material in the liner. In some cases, we were able to push the entire section into the liner with the bottom of a plastic cup, and to preserve its integrity that way. Where that was not possible, we were at some other times able to extrude the section intact into a split liner, then close it with duck tape. Where the core section could not be kept intact, separate samples were bagged according to their depth in the core. We also kept all gravity cores and other bagged samples refrigerated, then transported them in the cold van to Lamont for initial processing along with the vibracores.

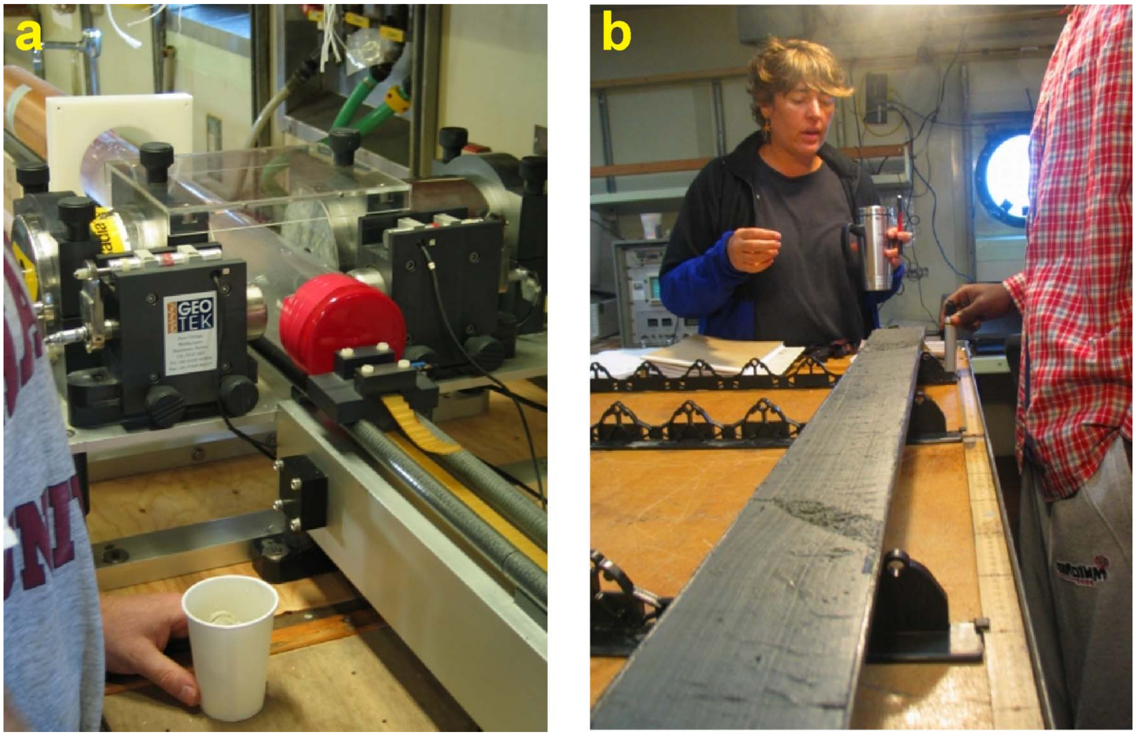

Figure 5. Core processing photos: (a) GeoTek core logger (here going through calibration with water-filled liner) and (b) a split core (from site 162_02, through outer-shelf channel-fill sediments: clay with sand lenses).

Multibeam Mapping
We made the best use of our 12 hours/day of non-coring time, after shifting to 12-hour operations, by conducting a multibeam bathymetry and backscatter survey with the *Knorr*'s 12 kHz SeaBeam system. Although the acoustic frequency is too low to be optimal for continental shelf water depths, the system still provided useful data to augment the available multibeam coverage. We designed track lines to extend the outer shelf multibeam coverage landward, in particular covering areas that included CHIRP seismic coverage but which had not previously been covered by multibeam (Fig. 1).

RESULTS

Cores are being processed and sampled. Results will be available in the coming year.

IMPACT/APPLICATIONS

In the long term, by improving our understanding of complex sedimentary systems on the continental shelf, we improve our ability to predict sedimentary properties based on understanding of environmental and geologic conditions in a region.

In the short term, the results of our coring will have immediate impact on the modeling work associated with the 2006 Shallow Water Acoustic program, which is focused in the same study area. These results, combined with the Geoclutter and SWA06 chirp data, will enable us to model sediment geoacoustic properties throughout the acoustics survey region.

RELATED PROJECTS

This project is most closely tied to the ONR SWA06 program, which this last summer conducted a 4-ship acoustics experiment in the same study area. Understanding the seabed geoacoustic properties along the various propagation path is a critical need for the modeling component of this program. The SWA06 web site is: http://www.apl.washington.edu/projects/SW06/.

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